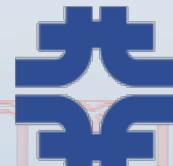
The NOvA logo is repeated here, showing the 'N' shape above the letters 'OvA' in a rainbow gradient.

Current Status and Future Reach

Mathew Muether



Fermilab

Presented at NOW 2012 for the NOvA
Collaboration

Outline

- NOvA – NuMI Off-Axis ν_e Appearance Experiment
- Flagship Intensity Frontier experiment at Fermilab when we turn on in 2013
- Project consists of 3 main components:
NuMI (Neutrinos from the Main Injector) upgrade, near detector at Fermilab and far detector located in

Ash River, MN



NOW 2012

M. Muether

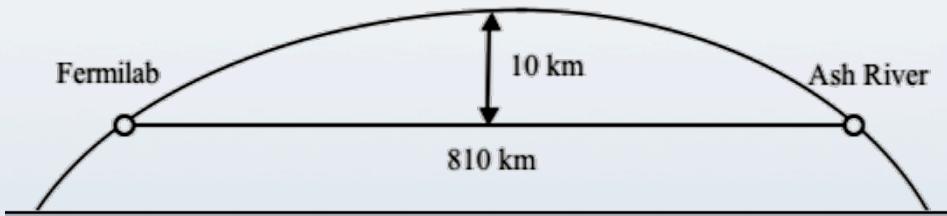


This talk will cover:

- Experimental Design
- Data from the prototype near detector
- Current status of the project
- Expected physics sensitivities
(NOvA is extremely active right now)

NOvA Program

- Long baseline neutrino oscillation experiment; 14 mrad Off-axis @ L/E ~ 400 km/GeV
- Near detector to characterize the beam
- Far detector for oscillation study



- Physics scope:

$\nu_\mu \rightarrow \nu_e$ appearance

- Measure θ_{13}
- ν mass ordering
- CP violating phase

$\nu_\mu \rightarrow \nu_\mu$ disappearance

- Precision measurement of θ_{23} , $|\Delta m_{23}^2|$

Cross-sections from near detector
Other exotics

NOvA Collaboration



ARGONNE NATIONAL LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
UNIVERSITY OF CINCINNATI

FERMILAB
HARVARD UNIVERSITY
INDIANA UNIVERSITY
IOWA STATE UNIVERSITY
MICHIGAN STATE UNIVERSITY
UNIVERSITY OF MINNESOTA – CROOKSTON
UNIVERSITY OF MINNESOTA – DULUTH
UNIVERSITY OF MINNESOTA
UNIVERSITY OF SOUTH CAROLINA
SOUTHERN METHODIST UNIVERSITY
STANFORD UNIVERSITY
UNIVERSITY OF TENNESSEE
UNIVERSITY OF TEXAS AT AUSTIN
TUFTS UNIVERSITY
UNIVERSITY OF VIRGINIA
WICHITA STATE UNIVERSITY
COLLEGE OF WILLIAM AND MARY



BANARAS HINDU UNIVERSITY
UNIVERSITY OF DELHI
INDIAN INSTITUTE OF TECHNOLOGY,
GUWAHATI
INDIAN INSTITUTE OF TECHNOLOGY,
HYDERABAD
UNIVERSITY OF HYDERABAD
UNIVERSITY OF JAMMU
PANJAB UNIVERSITY



LEBEDEV PHYSICAL INSTITUTE
INSTITUTE FOR NUCLEAR RESEARCH,
MOSCOW



UNIVERSITY OF ATHENS



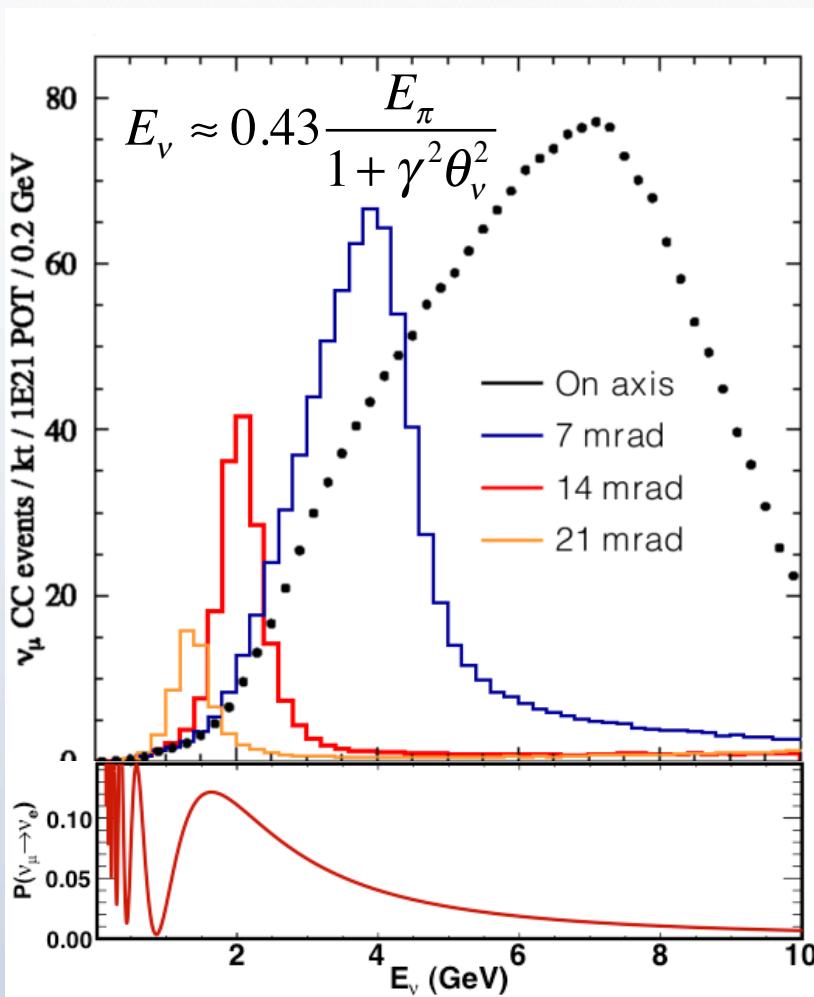
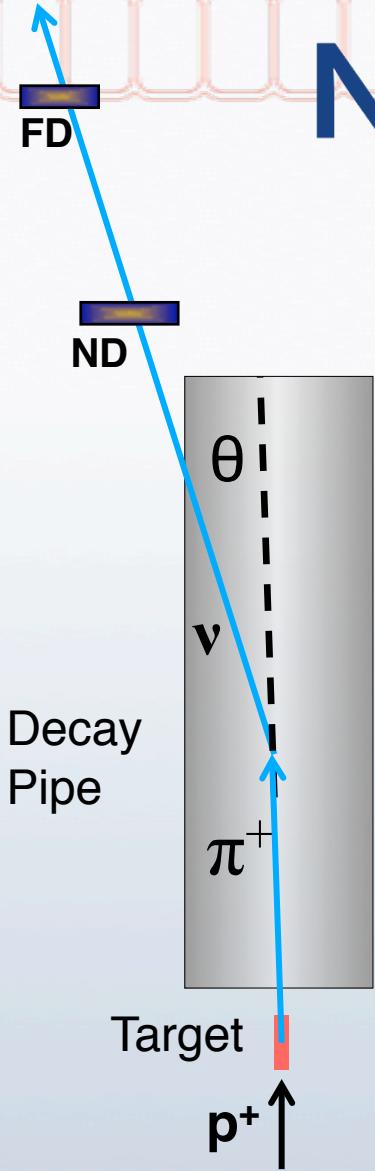
UNIVERSITY OF SUSSEX



INSTITUTE OF PHYSICS OF THE ACADEMY
OF SCIENCES OF THE CZECH REPUBLIC
CHARLES UNIVERSITY IN PRAGUE,
INSTITUTE FOR PARTICLE AND NUCLEAR
PHYSICS
CZECH TECHNICAL UNIVERSITY

**150+ scientists and
engineers from 33
institutions, 6 countries**

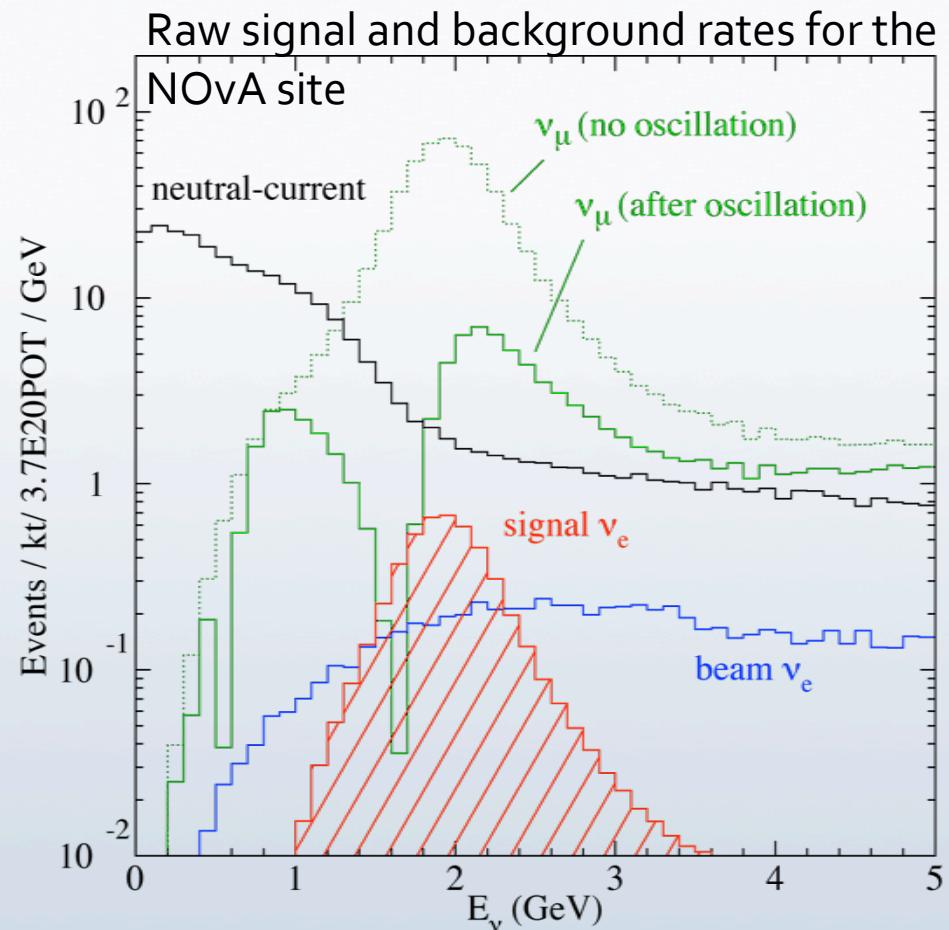
NuMI Off-axis Beam



- NOvA detectors will be placed 14 mrad off-axis in a narrow band beam
- Increases flux near oscillation maximum
- Reduces high energy NC background events
- Doubling power from 350kW to 700 kW during ongoing shutdown

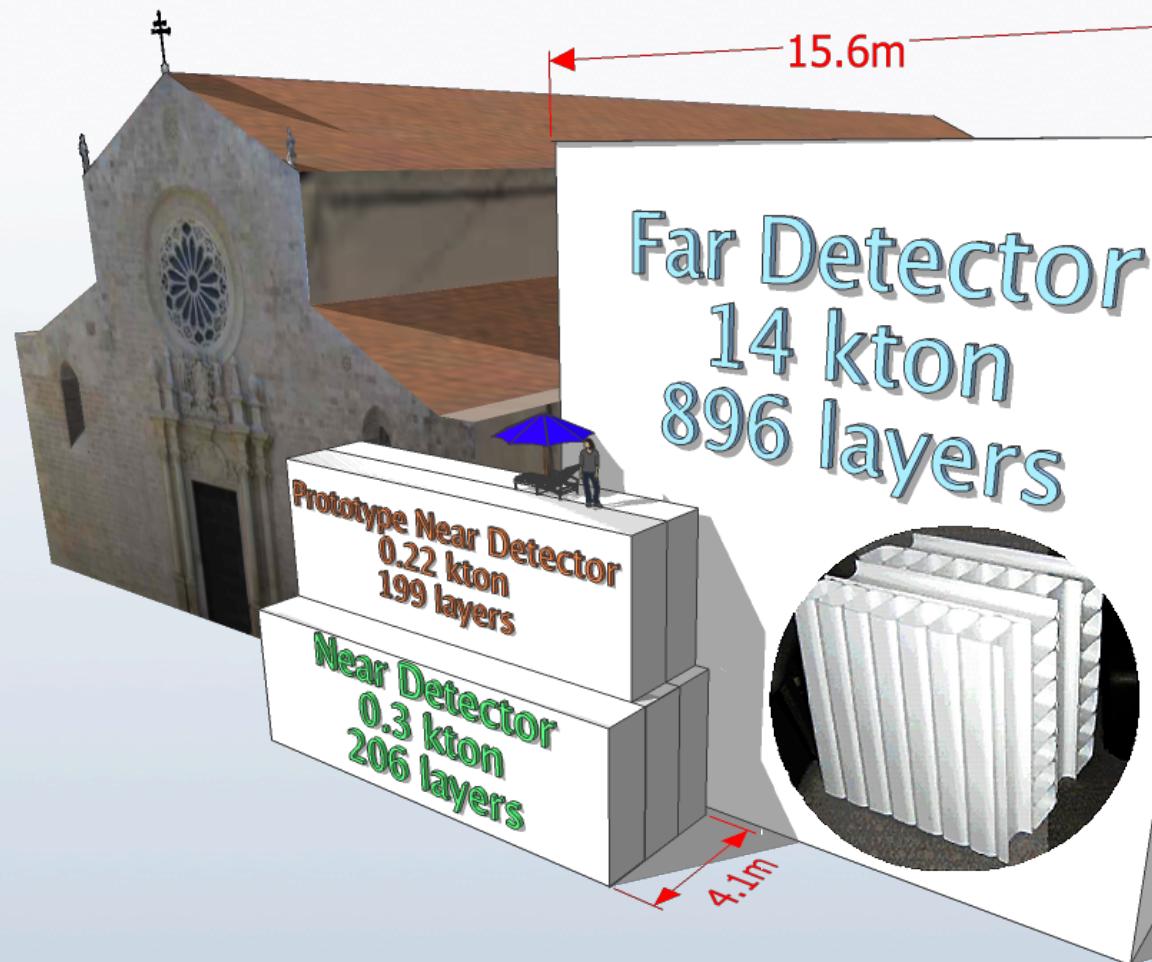
Design criteria

- Optimized ν_e detection efficiency for ν_e appearance measurement.
- Suppression of ν_μ CC and NC backgrounds at the 99% level
- Energy resolution small compared to signal width:
 - Less than 8% for ν_e Charged Current events
 - Less than 4% for Quasi-Elastic ν_μ Charged Current



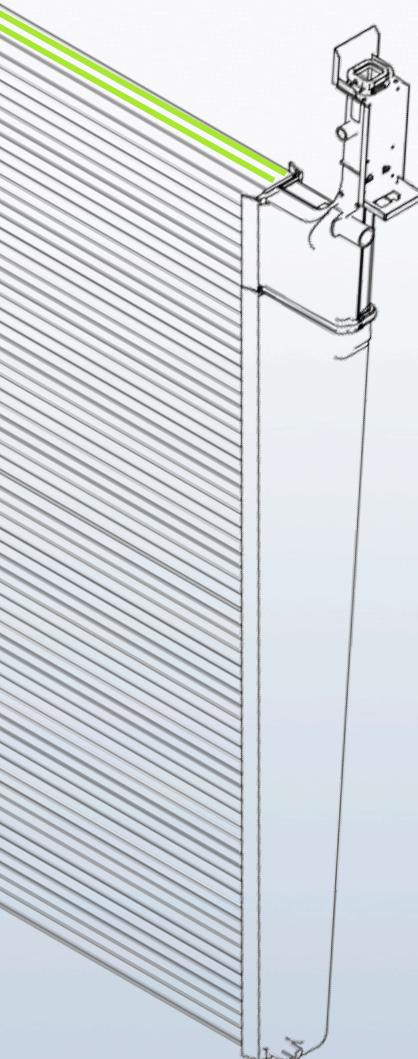
Interaction spectra at 810km, 14 mrad off-axis.
Oscillations: $\Delta m^2 = 2.5 \times 10^{-3} \text{ eV}^2$, $\sin^2(2\theta_{13}) = 0.01$

NOvA Detector Suite



- Tracking Calorimeters:
- Highly Segmented (Alternating X/Y)
 - Low Z (PVC and Oil)
 $X_0 \approx 40\text{cm}$, $R_m \approx 11\text{cm}$
 - 65% Active Volume
- ND: 1 km from NuMI
- 105 m underground
- FD: 810 km baseline
- Surface Detector
 - Overburden >10 radiation lengths

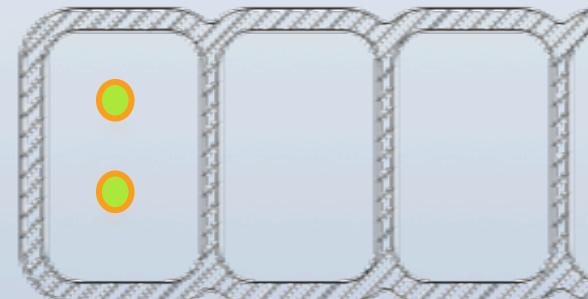
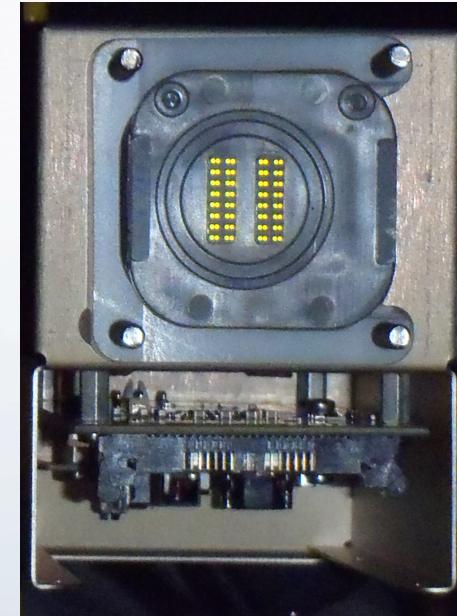
Detector Module



NOW 2012

- Cross-section of cell 4cm X 6cm
- Runs entire width of detector (15.6m for far detector)
- Filled with scintillator and instrumented with looped wavelength-shifting fiber
- 32 sealed extruded PVC cells
- Both ends of looped fiber routed to an optical connector
- 11,500 km of wavelength shifting fiber in total
- 10.5 million liters of scintillator (or 14 million wine bottles worth)

M. Muether

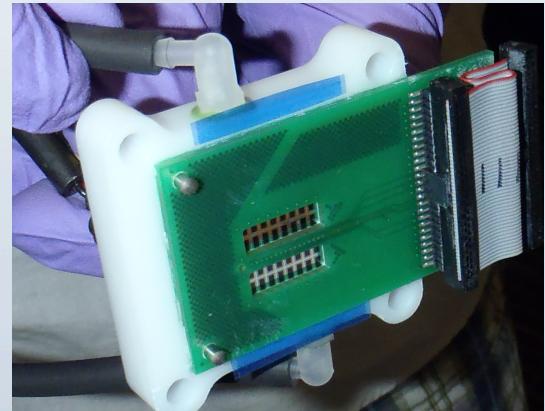
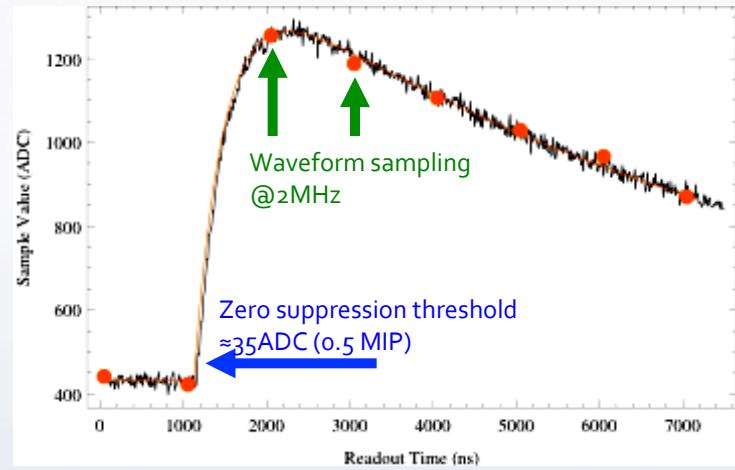


8

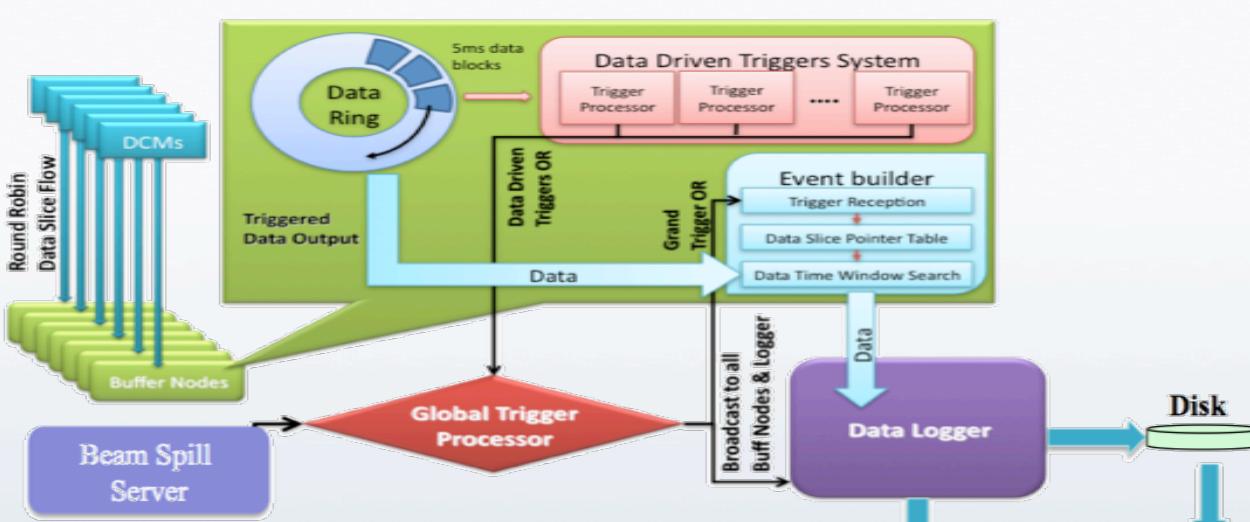
Detector Readout



- Array of 32 avalanche photodiodes mated to optical connector
- 85% QE for 520 – 550 nm light.
- Gain of 100 @ 375 volts.
- Controlled environmental conditions
- Actively cooled to -15 C.
- 38 pe signal from MIP at far end of cell (10-12 MeV dep. en)
- Signal digitized by on module front end electronics
- 10-15 pe threshold for data written out
- ~12,000 APDs on FEBs at far detector



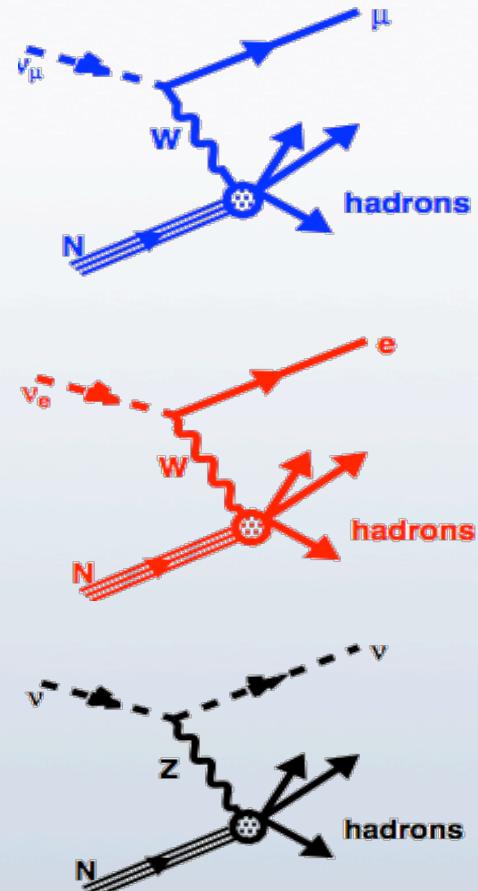
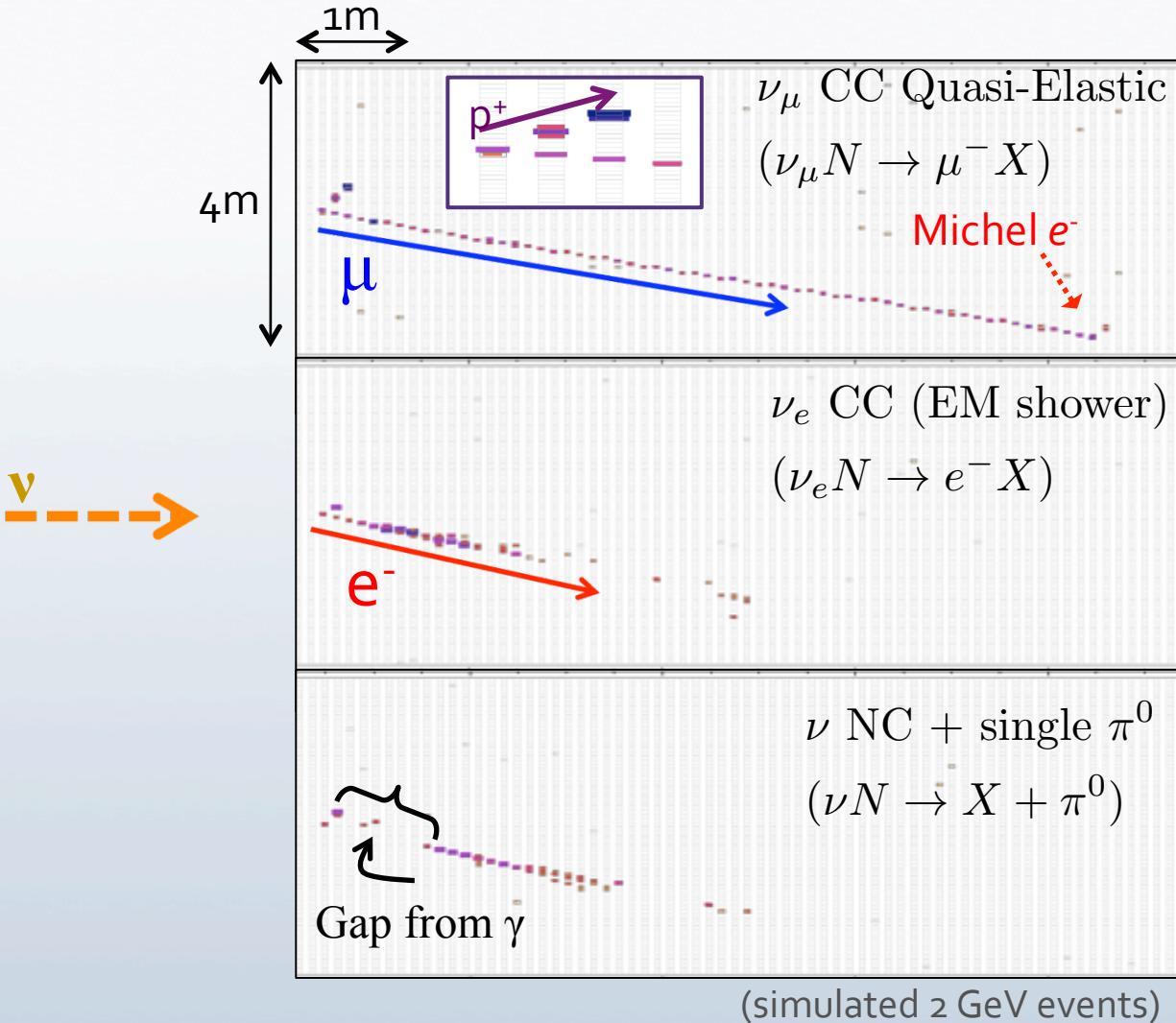
Data Acquisition



- 64 FEBs feed a Data Concentrator Module which packages and passes the data to a processing farm.
- Data is continuously buffered for several seconds until the arrival of a software spill trigger at which point it is written to disk.
- Beam spill and data driven triggers are available
- System is synchronized by an external timing system to GPS



Expected Event Views



System Prototype

- Prototype Near Detector on the Surface (NDOS) constructed in a mock far detector environment.
- Collecting cosmic and neutrino data since October 2010



- Invaluable in understanding production, installation, integration, and operations.

Location of Prototype

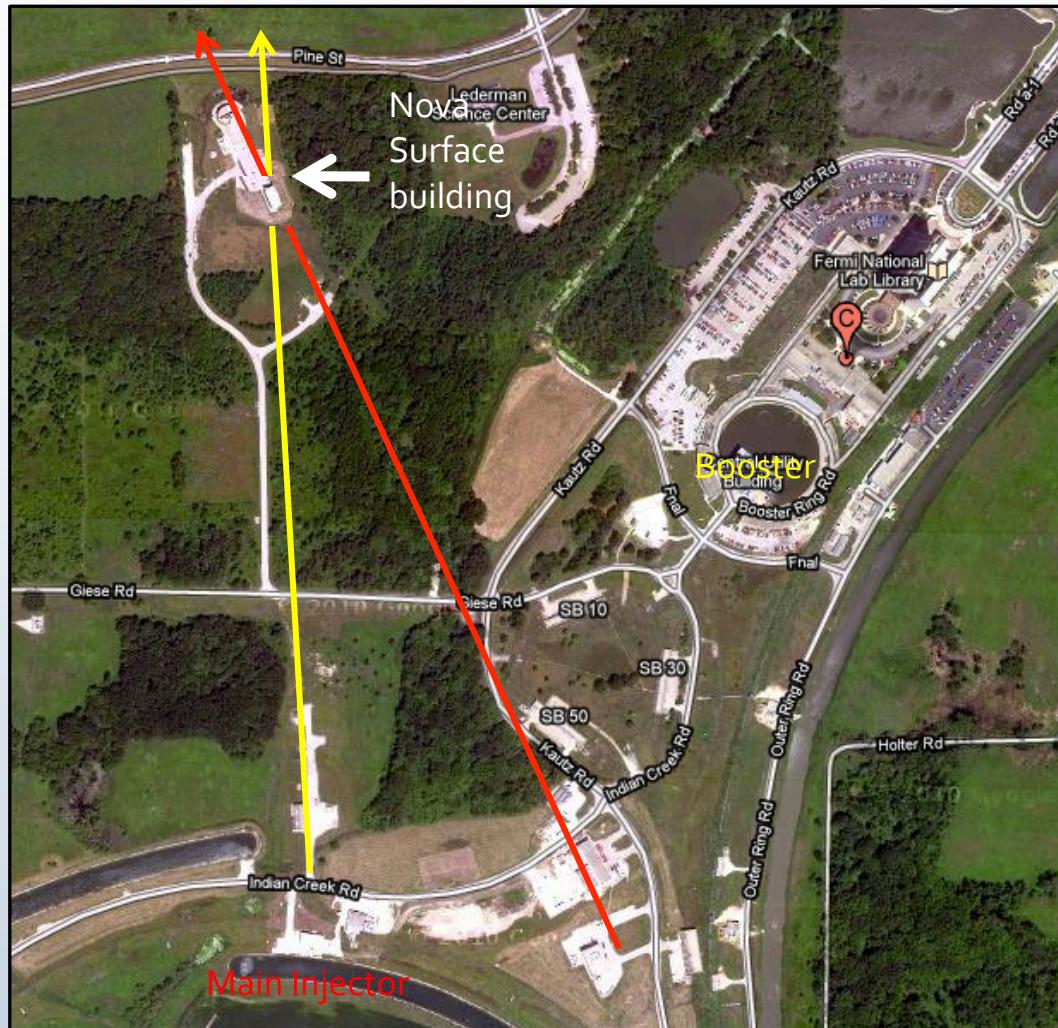


110 mrad off NuMI axis due to surface position

500 μ s wide trigger window @ 0.4 Hz

On-axis for booster (but rotated)

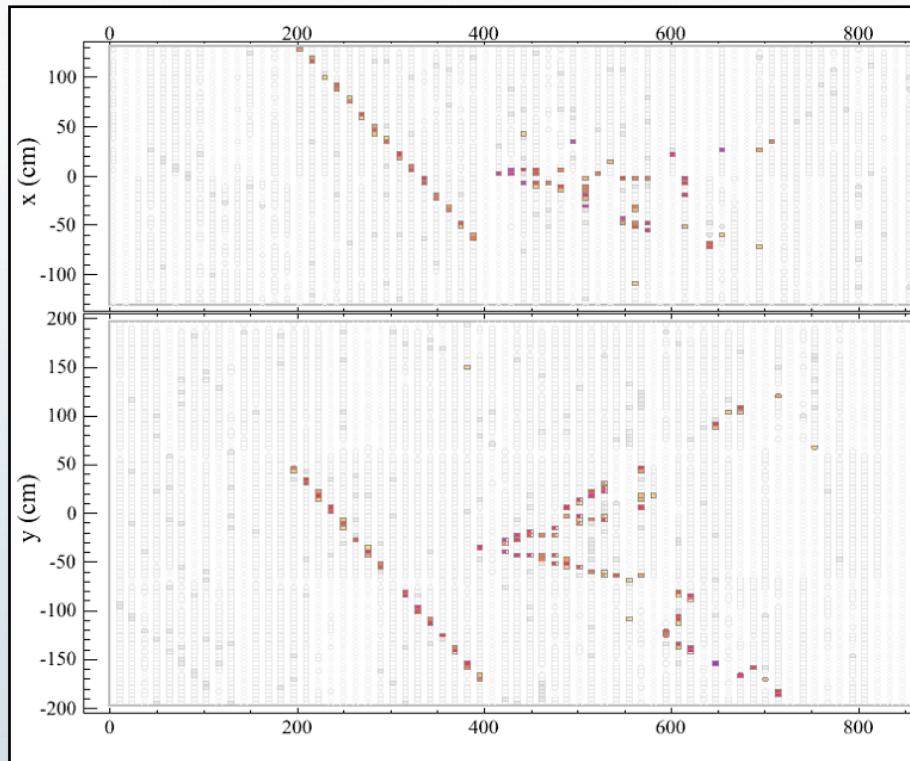
500 μ s wide trigger window @ 1.2 Hz



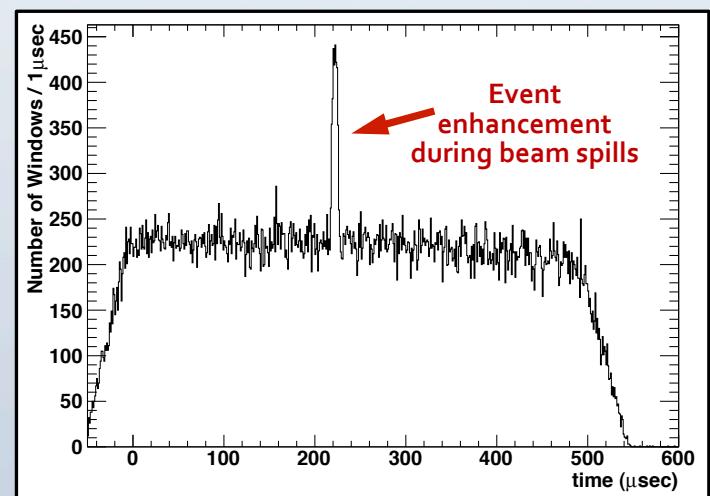
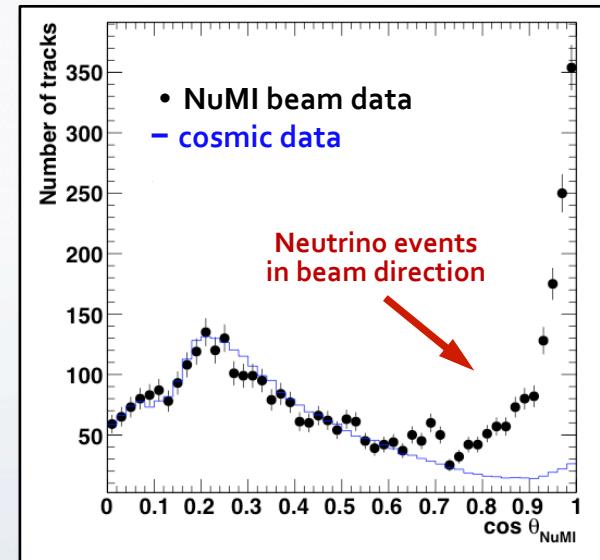
M. Muether

Prototype Events

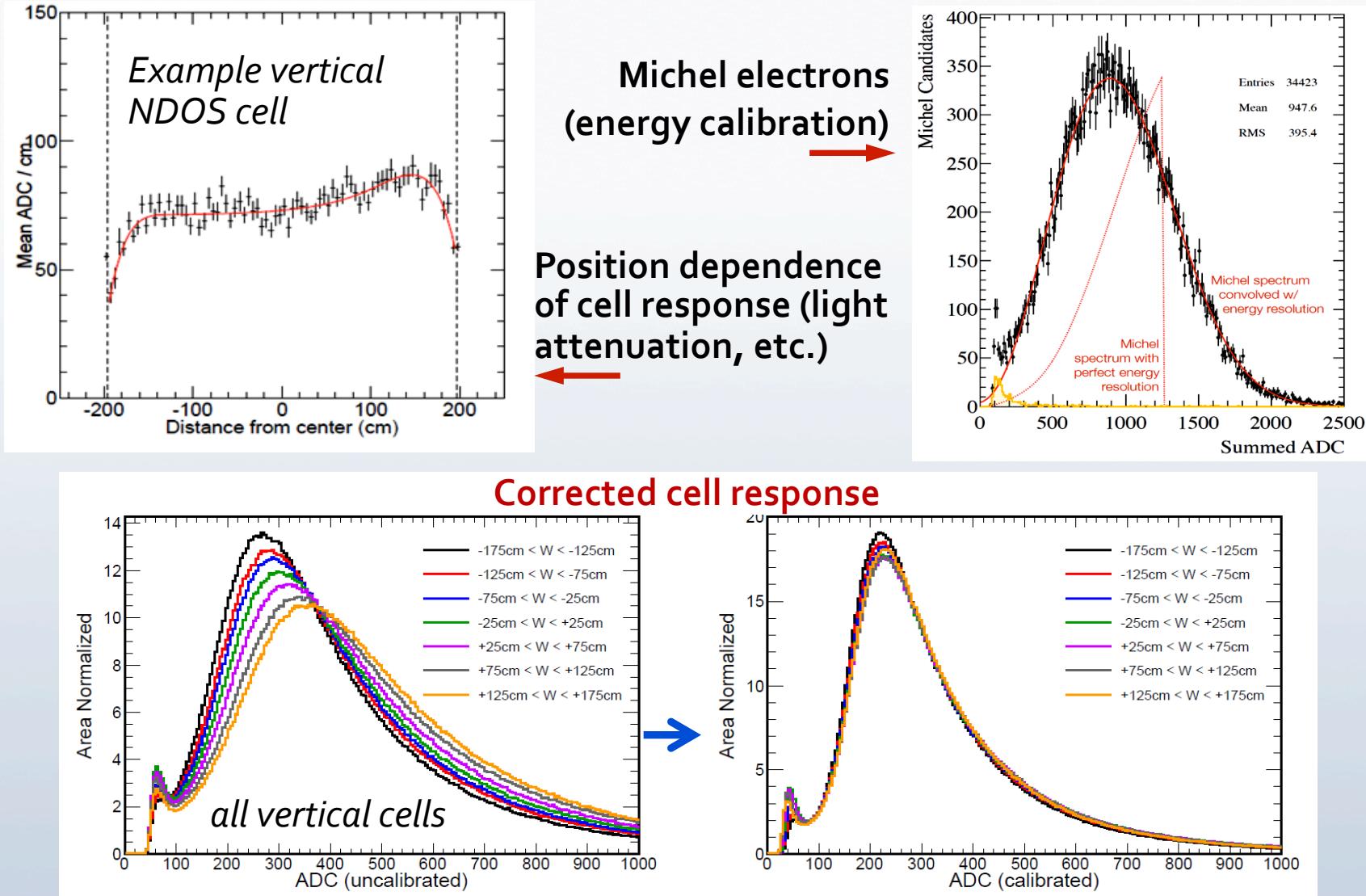
NuMI neutrino interactions



Similar distributions seen for the booster beam with lower efficiency



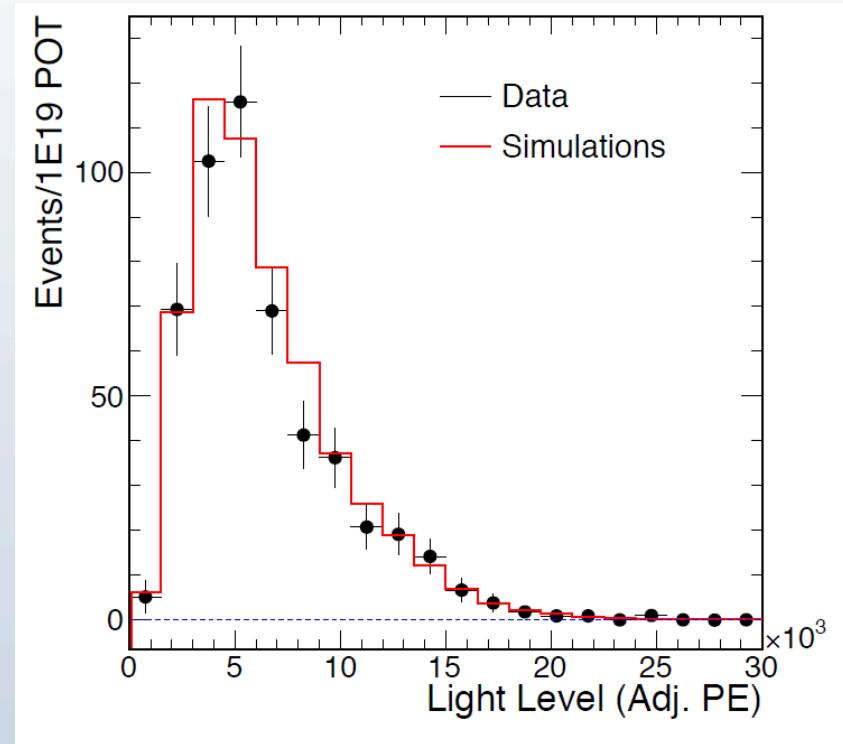
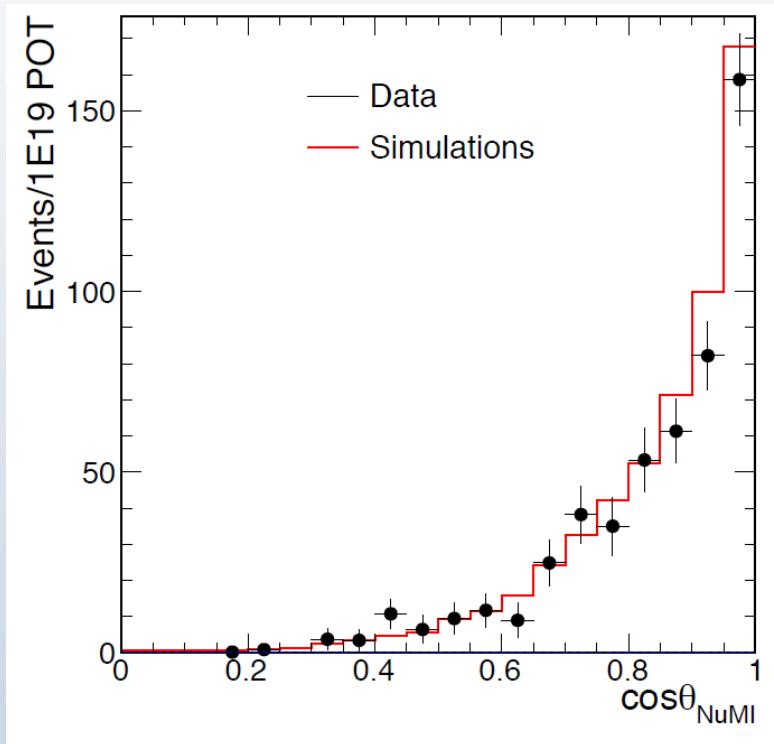
NDOS Calibration



NDOS Neutrinos

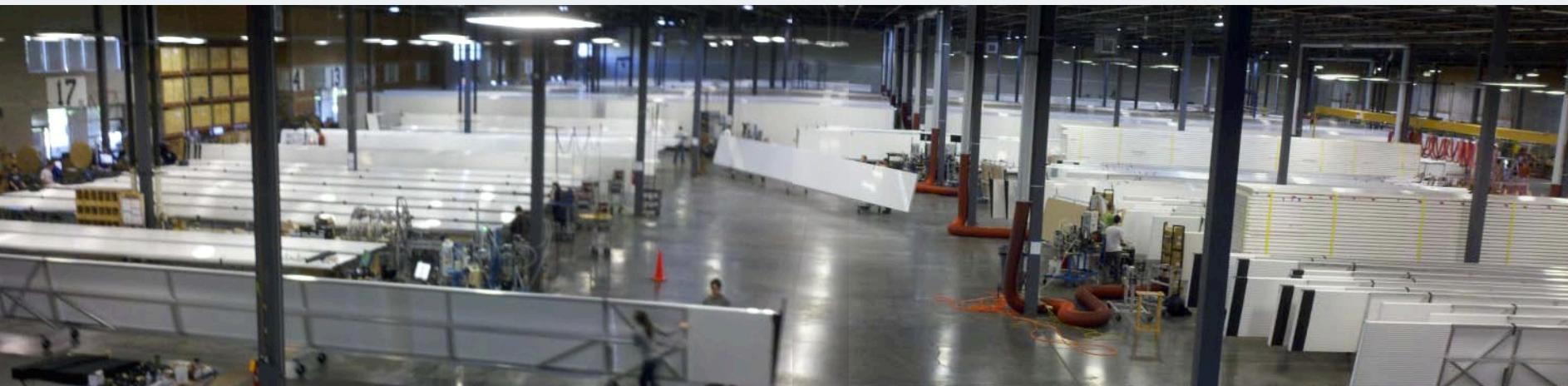
NuMI neutrino events at NDOS

- Two example distributions: *angle of primary track w.r.t. the neutrino beam, and total visible energy [in photoelectrons]*
- Our Monte Carlo simulation agrees well with observations



Quick Survey of Project Status

The module factory at the University of Minnesota is in full production and have stacks of modules ready to ship.



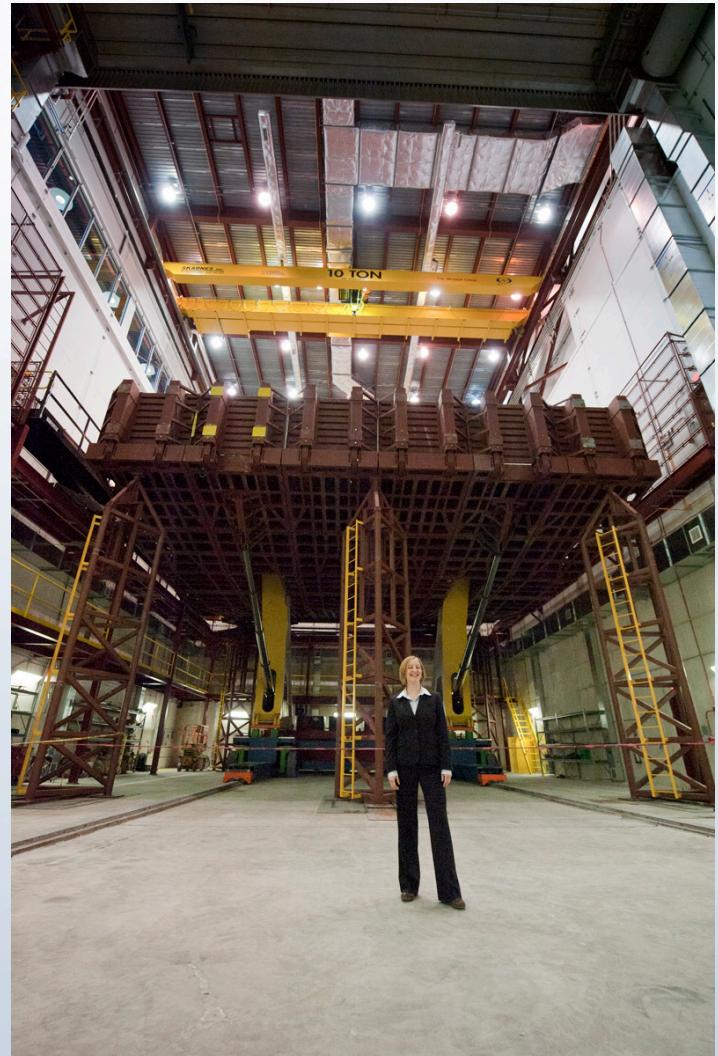
Far Detector Status

Building Complete!

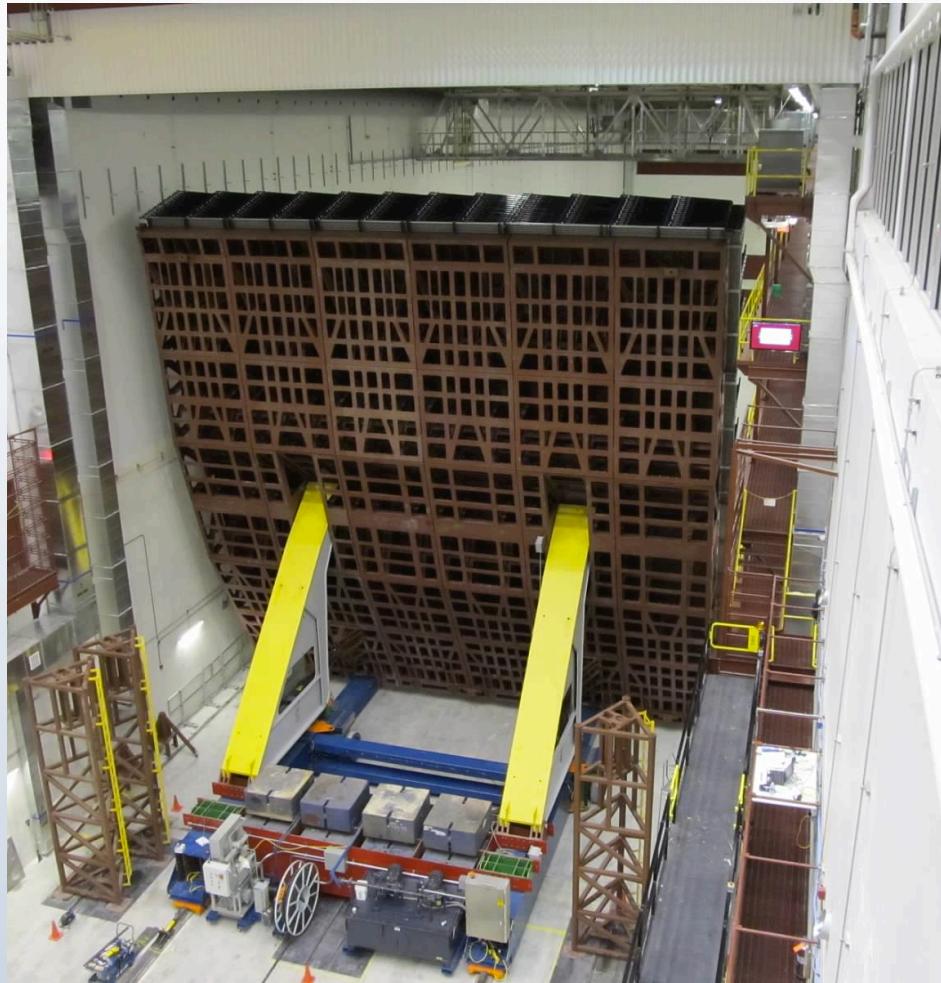


Far Detector Assembly

- The first block has been glued together and placement operations are complete!
- Watch the progress at http://www.fnal.gov/pub/webcams/nova_webcam/



Far Detector Assembly



Far Detector Assembly



NOvA Experiment - Ash River, MN

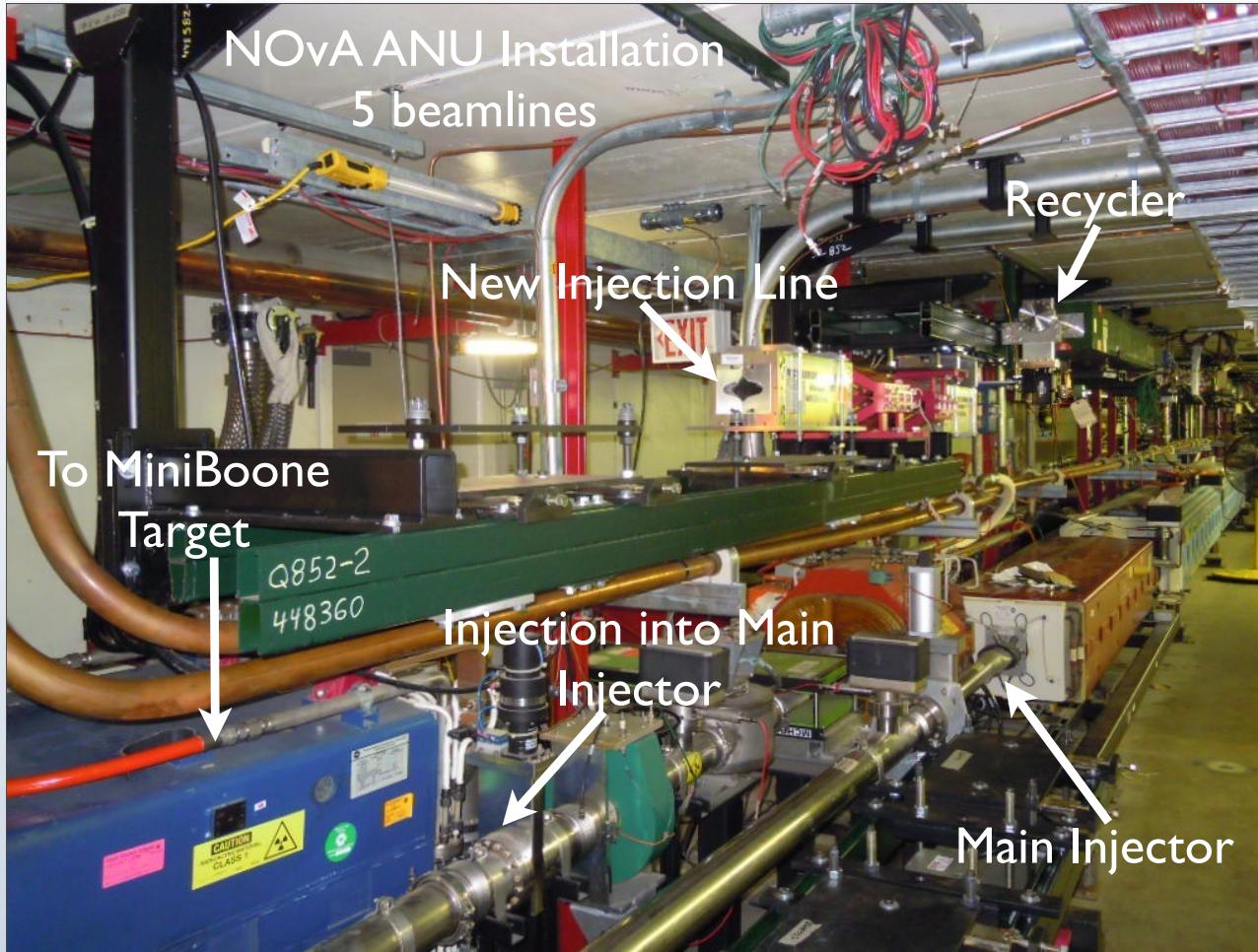
Far Detector Assembly



Near Detector Status



Beam Upgrade



Wednesday, July 18, 2012

Following the accelerator shutdown this spring work has began to upgrade the NuMI beam line to 700kW.

- Turn Recycler from antiproton to proton ring
- Shorten Main Injector cycle from 2.2 seconds to 1.33 seconds
- Overhaul of NuMI target station for 700 kW running

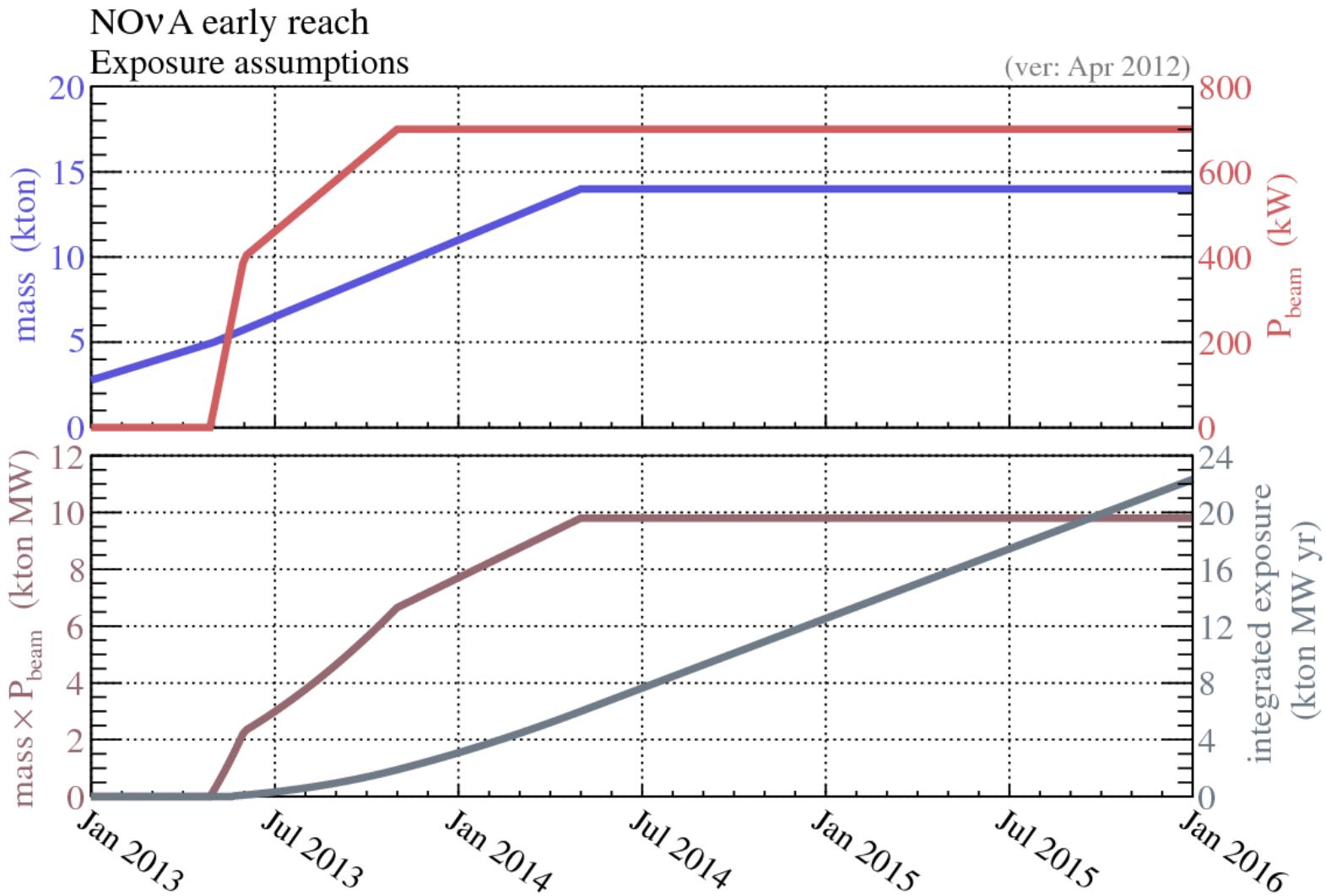
This work is expected to be completed by spring 2013.

Physics Reach

The following sensitivities assume

- $\sin^2 2\theta_{13} = 0.095$
- Optimization for $\sim 4\%$ oscillation probability
- 10% uncertainty on backgrounds
- 41% (ν) and 48% (anti- ν) signal efficiency

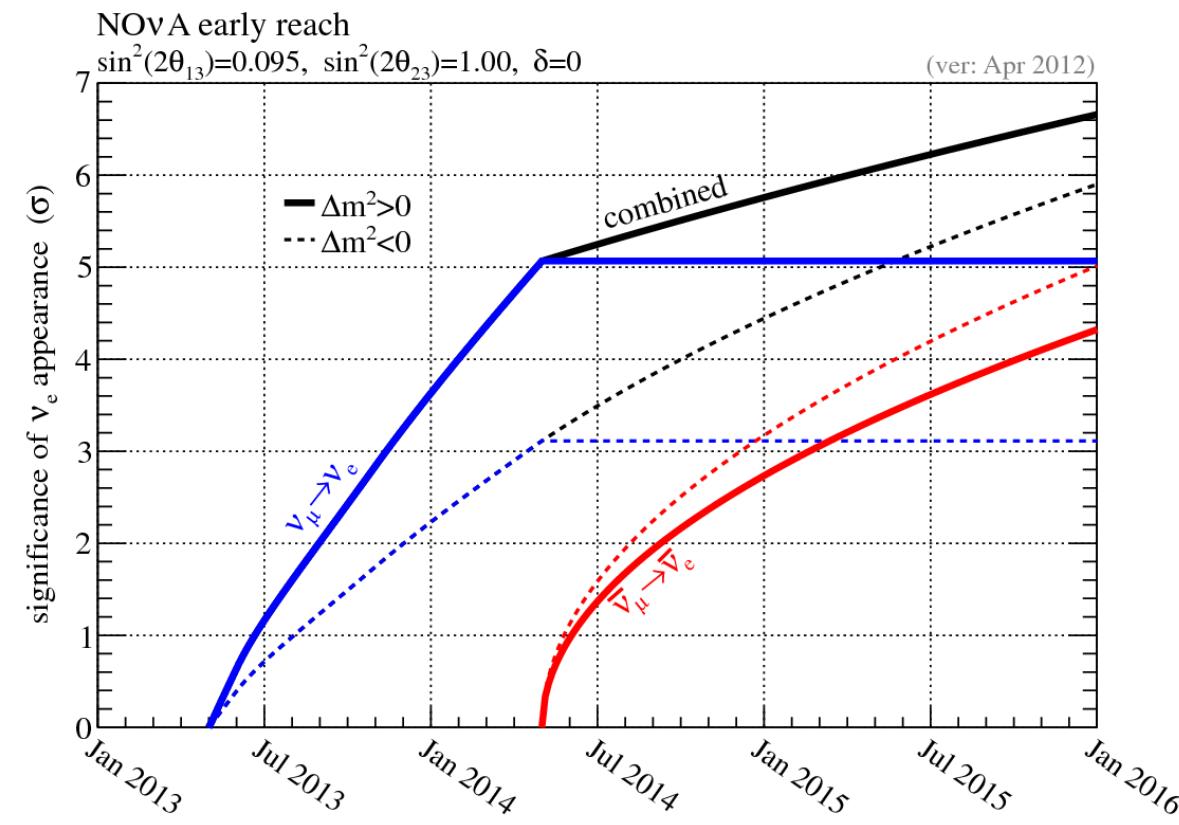
Expected exposure



Initial ν_e Appearance Reach

Will start with ν running

- Can switch to $\bar{\nu}_\mu$ any time, optimizing the run plan based on our or others' results
- 5 σ observation of $\nu_\mu \rightarrow \nu_e$ in first year if NH
(even with partial detector and beam commissioning!)



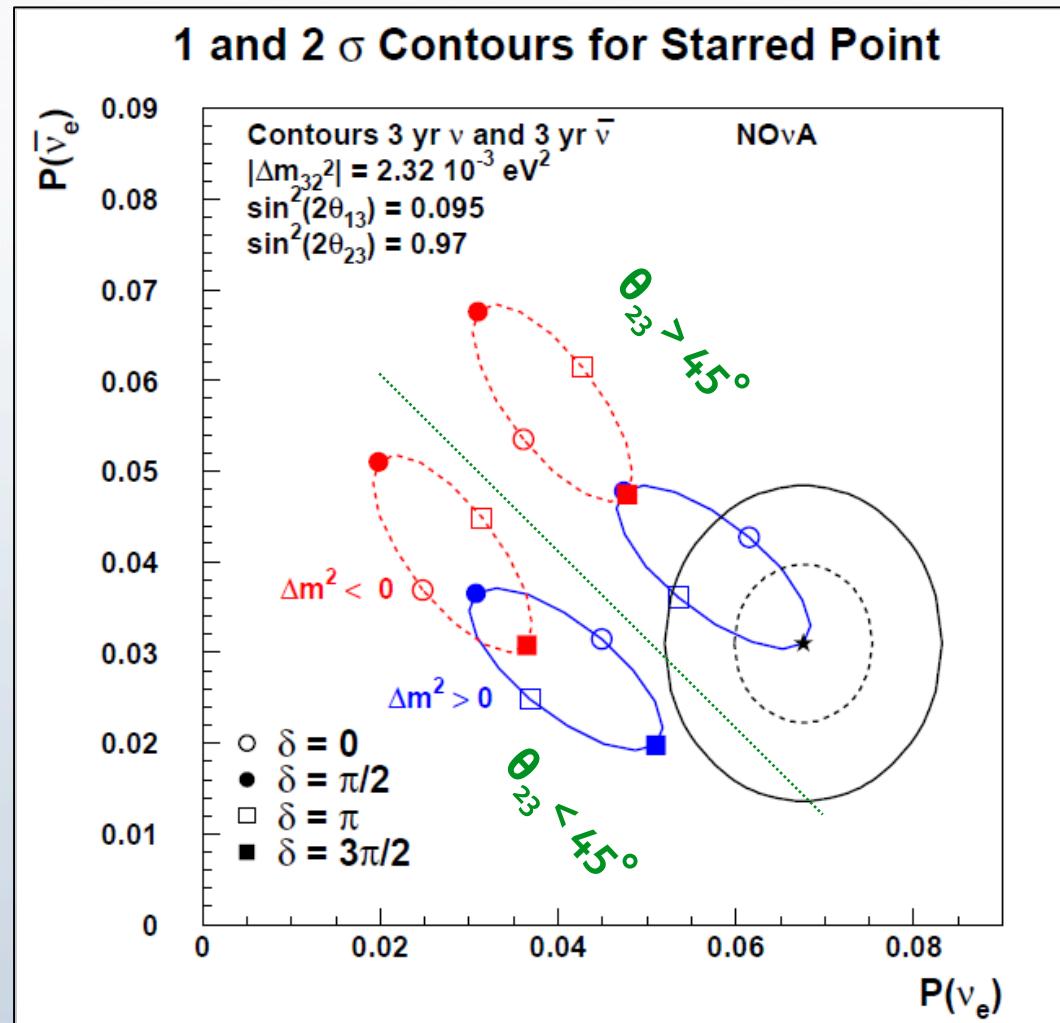
Example measurement

NOvA will measure:

$P(\nu_\mu \rightarrow \nu_e)$ at 2 GeV
and

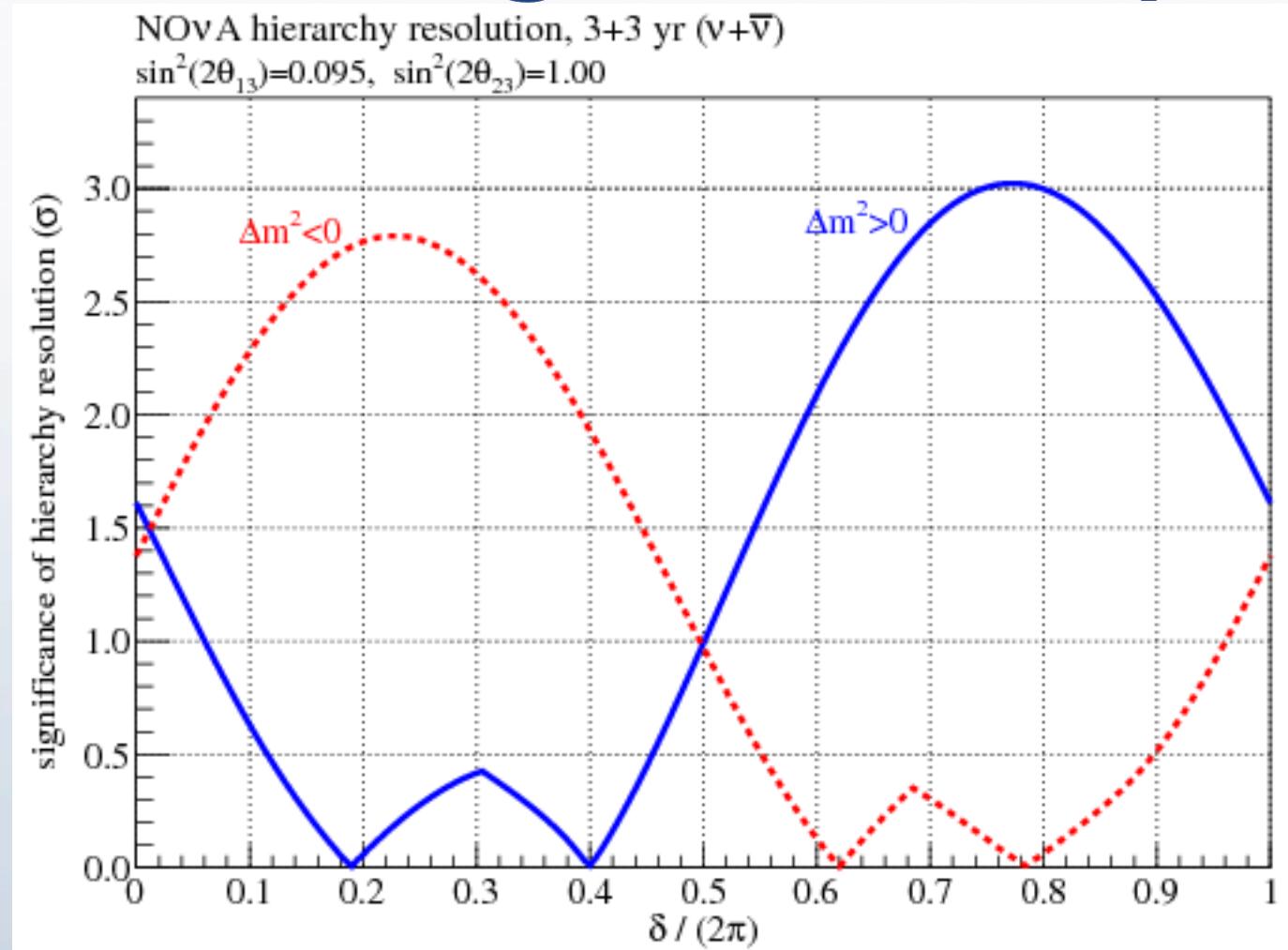
$P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ at 2 GeV

- Starred point is a example NOvA measurement with 1- and 2-sigma contours.
- Depends on CP phase δ , $\text{sign}(\Delta m^2)$, and $\sin^2(2\theta_{23})$.
- Red and blue ellipses show expected oscillation probabilities for choices of these parameters
- Simultaneous information on all three parameters



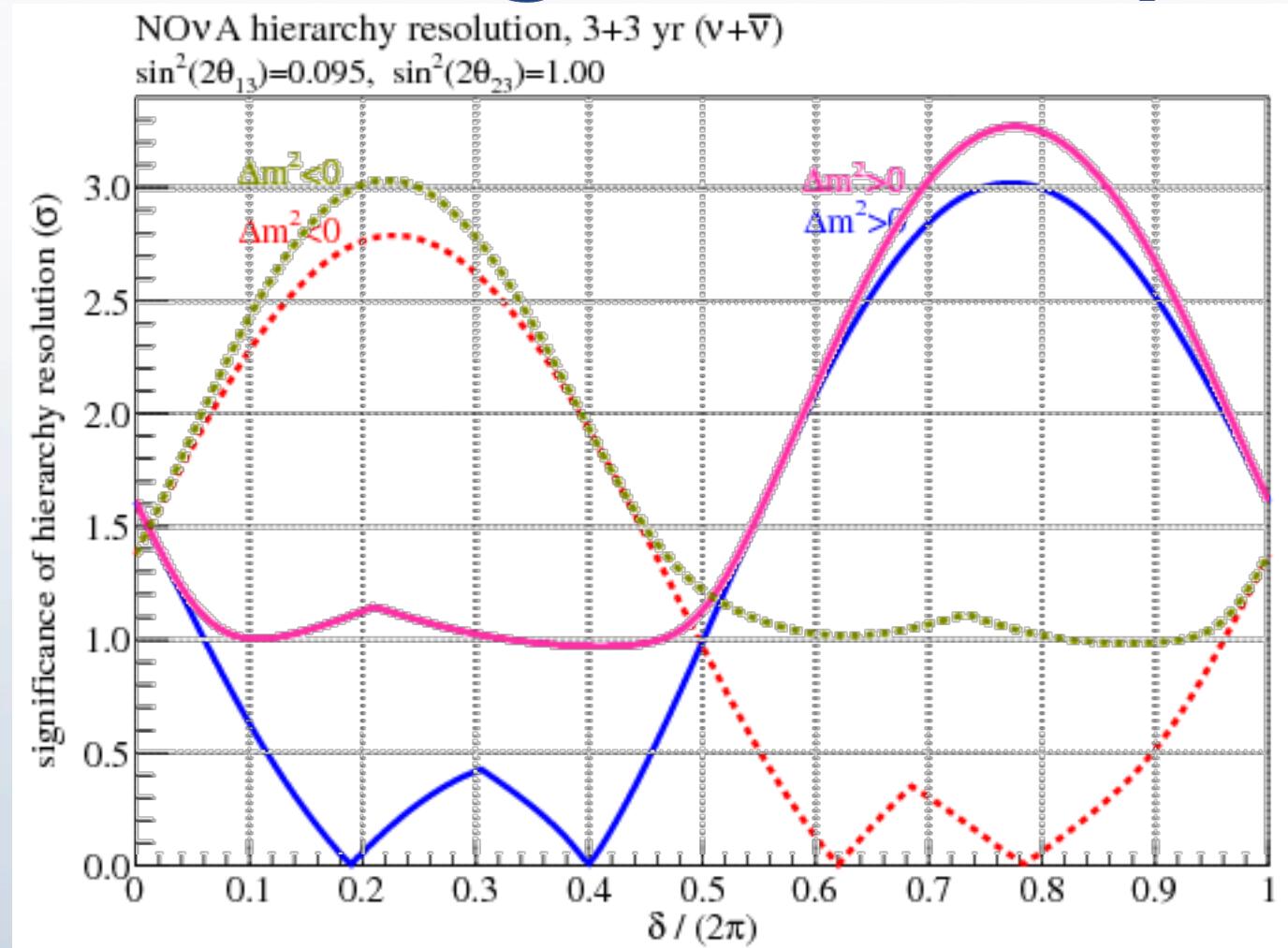
Mass ordering sensitivity

Significance with which NOvA can establish the mass ordering

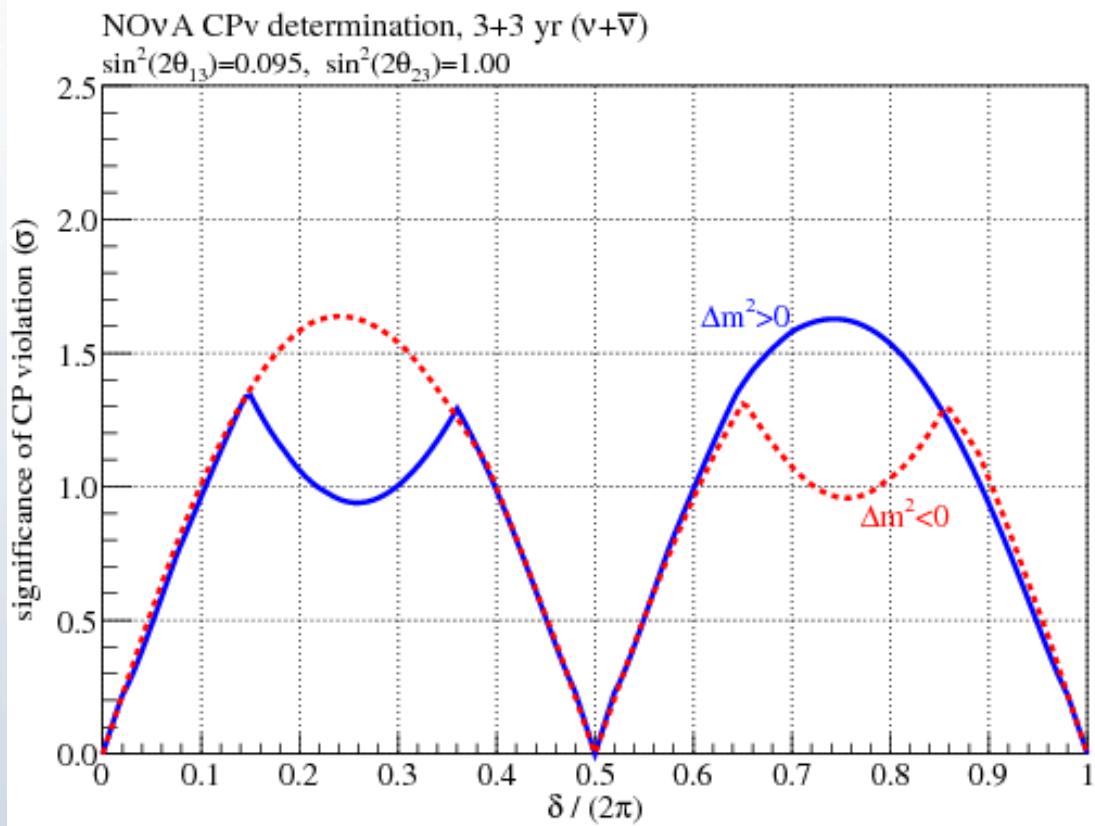


Mass ordering sensitivity

Significance with which NOvA can establish the mass ordering (red and blue) and with T2K data (5.5×10^{21} POT) shown in pink and green



CP Violation Sensitivity

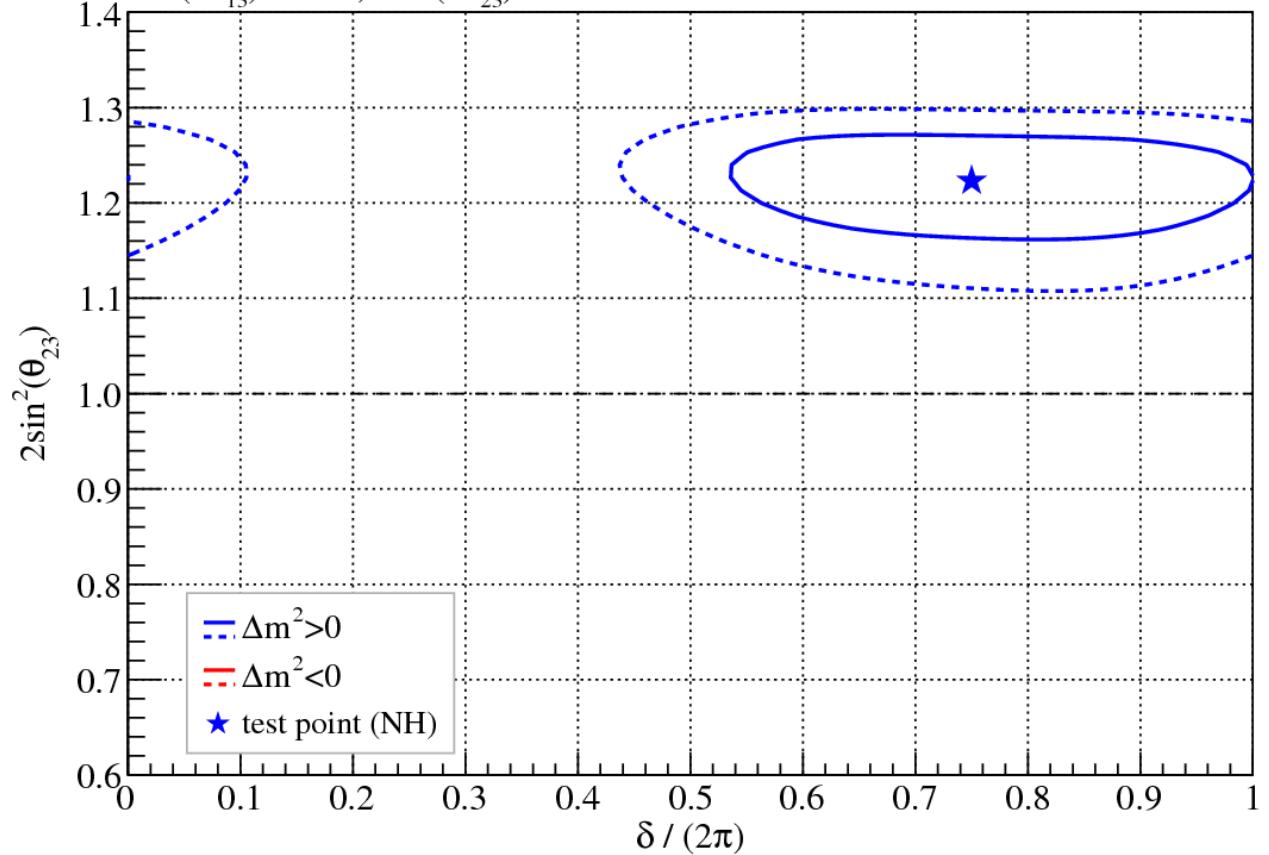


Significance with which
NOvA can establish CP
violation alone (red and blue)
and with T2K data (5.5×10^{21}
POT) shown in pink and green

θ_{23} octant sensitivity

The contours are 2D confidence intervals, representing our sensitivity to a joint measurement of $2\sin^2(\Theta_{23})$ and δ

Example NOvA 1σ and 2σ contours, 3+3 yr ($\nu + \bar{\nu}$)
 $\sin^2(2\theta_{13})=0.095$, $\sin^2(2\theta_{23})=0.95$



Conclusion

- NOvA Far Detector construction is underway. First data expected in spring 2013.
- NuMI 700 kW upgrades are also progressing
- Near Detector excavation has begun
- NDOS has provided a valuable training ground
- The large measured value of θ_{13} puts our mass hierarchy, δ_{CP} , θ_{23} goals within reach, along with our extended physics program.



Please stay tuned:
<http://www-nova.fnal.gov>
@NOvANuz on Twitter
<https://www.facebook.com/novaexperiment>

Backup

